HUMAN FACTORS SURVEY OF AVIATION MAINTENANCE TECHNICAL MANUALS

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Abstract

The reported work is part of a 3 phased effort to identify human factors issues in the development of aviation technical manuals, and make recommendations for the improvement of those documents. Phase 1 of this research effort surveyed the procedures used by five manufacturers to develop maintenance documentation. Several human factors issues were identified in the development process employed by these manufacturers. They included the reactive rather than proactive use of user evaluations, the limited use of user input and procedure validation, no systematic attempts to track error, and the lack of standards for measuring document quality. Given the issues identified in Phase 1, the objective of Phase 2 was to gather information about errors in technical documents, manual usage rates, and user perceptions of manual quality. Respondents were asked to identify the types of problems encountered with technical documents, the impact of those problems, and suggestions for improving manuals. We also sought to gather information about the differences between manuals developed by different companies. Considering the variability of methods used by manufacturers to develop technical documents, it may be possible to identify techniques and procedures that result in more effective documentation.

Introduction

The Federal Aviation Administration has committed themselves to the goal of reducing fatal aircraft accidents by 80% of the 1996 baseline rate by the year 2007[1]. An important part of accident reduction is to reduce the number errors generated during the maintenance of aircraft. In an analysis of aircraft maintenance error causation, Johnson and Watson[2] identified information as being the highest ranked contributing cause, being implicated in approximately 38% of all maintenance errors. An analysis of NASA Aviation Safety Reporting System data regarding maintenance incidents found document procedures to be related to 60% of incident reports from 1986 to 1992 and 45% of incidents from 1996 to 1997[3]. Further analysis of the errors attributed to information revealed that incorrect data was a factor in only a small number of these cases, and many of those cases were user-initiated problems. More common were cases in which the information was not referred to, misunderstood, or disregarded in favor of an alternate method of performing a maintenance procedure. Given the number of cases in which technicians fail to properly utilize maintenance information; one might conclude that the problem should be addressed through training or disciplinary action toward the maintenance workforce. However, rather than indicating a systemic discipline problem with maintenance technicians, or laissez-faire attitude toward technical documents, it could reflect a problem with the usability of technical documents.

Maintenance manuals can contribute to maintenance error if they contain misleading information, insufficient information, or unclear procedures. Not only must the information be technically sound, it must also be presented in an effective manner. A term common to the computer industry that is applicable in this case is 'usability'. Usability can be defined in broad sense as "the ease with which a user can learn to operate, prepare inputs for, and interpret outputs of a system or component"[4]. When applied to aircraft manuals, usability includes the user experience of manuals; how easy they are to use, how well they match the technician's representation of a task, how easy they are to read and interpret, and how useful the information is they contain. The users experience of the manuals influences how they use them, and the degree to which users will refer to the document.

Background

The task of developing and revising maintenance manuals requires the coordination of multiple information sources across a number of departments within the management structure of the manufacturer. Engineering, technical support, customer service, and technical writing must integrate the most recent information from their respective sources to provide the technical base necessary to produce a technically sound document. Technical writers have the ultimate responsibility of verifying that they have the most recent and accurate information available on which to base technical manuals.

The accuracy of the information contained in maintenance manuals is of paramount importance and manufacturers have implemented multiple safeguards to protect against the inclusion of erroneous content. Document checklists, peer review, and software formatting have all been implemented to reduce the number of errors present in fielded maintenance manuals. Once released, each manufacturer has procedures for addressing problems that users encounter while using the manuals. The accuracy of maintenance manuals gets considerable attention from manufacturers and operators, and the continued application of computer technology to the technical writing task promises greater ability to verify the accuracy of technical information.

Phase 1

This phase sought to gain a working knowledge of the issues surrounding the development, revision, and distribution or aircraft maintenance technical manuals and the current industry procedures that address those issues. This information was gathered through the cooperation of multiple aircraft manufacturers and their personnel, including:

- Technical writers
- Customer service representatives
- Engineers
- Illustrators
- Department managers
- Manufacturer representatives

Information was collected through informal interviews and directed discussions. The topics covered in these interviews included:

- The process of developing and revising maintenance manuals

- The systems and procedures used to coordinate information from numerous sources within the organizational structure of the manufacturer.
- The solicitation and inclusion of user feedback into the development of technical manuals.
- The means used to identify, track, and reduce error in fielded technical manuals.

Industry Analysis

Who Writes Manuals?

The manufacturers differ considerably with regard to what they consider appropriate qualifications for a technical writer. For example, one company may hire mostly engineers while other companies hire a composite of mechanics, writers, and technicians. The make-up of the technical writing staff is potentially important, as the knowledge base of the writer may not match that of the user. In some cases, an engineer's cognitive representation of a mechanical system may be very different from that of a mechanic.

Error Tracking

Because of the amount and specificity of the technical information, all manufacturers invest considerable effort in verifying the accuracy of new maintenance procedures. The basic proofreading process is similar across manufacturers; however, the manufacturers vary markedly in the way they handle errors once they are identified. These differences stem from what point in the development a manufacturer chooses to track errors. The first point for tracking error is at the time of inclusion in the manual. If the development process includes a formal proofreading, errors can be recorded and tracked to identify trends. If there appear to be a pattern of errors, new procedures or training can be developed to eliminate this trend. Error identified at this stage is limited to problems in the execution of the writing process.

The second point in the process at which errors can be tracked is after the document is released to the user. User feedback allows the tracking of not only execution errors such as incorrect part references, but also planning errors such as confusing language or difficult procedures. Identifying and tracking error in a fielded manual requires formal procedures for customer communication and feedback.

All of the surveyed manufacturers have systems for proofreading new data before it is cleared for publication. For written procedures, the first level of proofreading usually consists of a peer review. Depending on the manufacturer, the next level of proofreading includes either a review by a group lead or a document checker. Illustrations are presented to the requesting writer to verify that the drawing meets the intention of the writer. Illustrations are then checked for non-technical errors such as line weights and call-outs. The level of formality with which these procedures is performed may differ between companies, but the basic tasks are the same. Where companies differ considerably is in the tracking of the errors identified during the proofreading process.

While all of the surveyed companies have error checking procedures, few have made attempts to catalog identified errors or identify error sources. For those that do catalog error, it is generally limited to process error, or errors found before the release of manual data. For each of the companies, there is a reluctance to maintain detailed records of past errors because of fear of how that information could be used. Employees are wary of error being traced down to the level of the individual for fear of punitive repercussions affecting pay or promotion. The companies are also wary of maintaining a detailed error history because of exposure to liability or regulatory action.

Customer Feedback

Each of the surveyed companies maintains customer support networks that gather feedback from users and answer questions. Customer feedback can be gathered through mail, telephone hotlines, fax, Teletype, and email. In addition to direct contact with the manufacturer, factory representatives and services centers are available. Typically, problems reported through hotlines or customer support pertain to a specific issue associated with the manual (e.g. a question about a specific procedure) and reveals little about the users perception of the overall quality of the technical documentation. Companies have attempted to use surveys to solicit more general information about how they might better meet the needs of the users. Phone solicitations and mass mailing have been used to obtain user feedback. The quality of this information is often suspect because the feedback is usually not very specific and is frequently limited to blanket statements of like or dislike. On-site surveys and interviews were also performed in an attempt to improve the quality of feedback gathered through user survey. Whether it is a function of the unexpected nature of the unsolicited contact, the lack of salient examples of problems, or low motivation, the average response to manufacturer-initiated surveys adds little to the information already gathered through user-initiated contacts.

Validation

Rather than relying solely on user feedback to identify problems with new or modified procedure instructions, some manufacturers have used validation techniques to evaluate the quality of the procedures. Validation involves actual users attempting to complete a procedure and reporting any difficulties encountered. The validation should be performed under conditions that replicate the working environment as closely as possible, so that performance can be expected to be similar to the real world. Validation is an excellent means of testing the maintenance data without the potential for costly mistakes. Procedure testing has the added benefit of encouraging communication between the user and writer. A procedure may appear to be accurate and sound, but when a user attempts it, they find an easier way, or suggest information that might aid a mechanic in completing the procedure. In some cases, safety or economic limitations preclude the validation of a procedure through user performance. For example, many troubleshooting procedures cannot be validated unless a specific component is damaged. To simulate a damaged component, or to actually damage a component may not be economically feasible or may impose a potential safety risk. In these cases, validation procedures can be extended to include simulated task performance and user analysis of instructions. Simulation would involve a user working through a task in accordance with the maintenance instructions, without actually performing the task. Analysis involves a user read through of instructions with the purpose of identifying potential problems or concerns. Analysis, simulation, and performance can be thought of as a set of validation "tools" to be applied as appropriate in light of the constraints imposed by the task to be evaluated.

All of the companies surveyed have used some form of procedure validation, but most use it in an unsystematic fashion. It is policy in some companies to validate procedures that a writer is unsure of, or that have gotten negative comments from field users. In most cases, validation testing at these companies is done by the actual writer, or the writer and a company service center mechanic. The choice of whether or not to validate maintenance procedures is usually part of a customer support strategy, and must be weighed against the total cost of an aircraft program. Because access to an actual aircraft may be limited during development, maintenance data may be developed using only engineering documents. Designing procedures from engineering documents may lead to procedural problems (i.e. difficulty accessing components, interference from conflicting components) that would be otherwise obvious when looking at the actual aircraft. Because these issues are only identified after the aircraft has been in the field, it may be difficult to appreciate the potential cost benefits of procedure validation early in the manual development process.

Measures of Document Quality

None of the surveyed companies had an objective method for measuring the quality of manual data, rather each reporting customer satisfaction as the primary measure of document quality. Measures of customer satisfaction are based on feedback gathered through customer support. In some cases, user surveys conducted by industry journals are used as a benchmark for comparison with other manufacturers. Within the individual companies, quality is also judged on more subjective criteria including the degree to which the writing adheres to an established look, feel or style. Decisions regarding the details of wording and writing style are left to the judgment of the writer and through the feedback of lead writers an appreciation for these subjective criteria is conveyed to less experienced writers. Whether it is performed by a peer or a formal evaluation procedure, all manufacturers audit revised data for technical accuracy in terms of procedural logic, efficiency, source data accuracy and completeness. However, it should be emphasized that there is currently no independent measure of manual quality derived using psychometric principles. Instead, quality standards derive from company history and what users have accepted in the past.

Phase 2

In order to determine the potential effects of the procedures used by industry on document quality and usability, a survey was developed to measure technician perceptions of maintenance documents. In addition to general perceptions of documentation quality and usability, respondents were asked to compare the documentation produced by different manufacturers so that differences in user evaluation might be traced directly to the procedures used by a particular manufacturer.

Survey Description

The survey solicited information from the respondents about a number of areas including the aircraft they currently work on and their specialty area. Participants were then asked to identify the two aircraft with which they were most familiar, and to compare the frequency of errors, perceptions of quality, satisfaction, and usability, of those manuals. Next, the respondents were asked to report how frequently they had engaged in safety related maintenance behaviors, and to identify the consequences of errors or confusing information they have encountered in the manuals. Finally, information was solicited about document format preferences, and suggestions for improving the manuals. Biographical information, including education level and employment experience, was collected for the purpose of identifying any trends in user responses that may have been due to individual differences. Responses to assessments and ratings of the manual were reported using a 5-point Likert scale. Other data was recorded as discrete or narrative responses when appropriate.

Interviews

In addition to the questionnaire, site visits were made to one regional operator and two major airline facilities. Manual users working at these facilities were interviewed to verify the reliability and validity of survey responses, as well as providing additional detail and clarification of the survey data. Interviews were conducted with personnel involved in all areas of aircraft maintenance, including technicians, supervisors, engineers, parts supply, and task card writers. Interview participants were asked to identify areas of strength and weakness in the technical documentation provided by manufacturers, to compare and contrast different manufacturers, to assess the potential impact of document quality, and to make suggestions for any improvements that could be made to manufacturers' documents. When possible, interviews were conducted in groups of 2-3 individuals to facilitate discussion, while limiting peer influence that might be present in a larger group.

Results

Survey Response

Completed surveys included feedback from technicians at both line and heavy base maintenance facilities. Figure 1 shows the manufacturers of the aircraft that technicians maintain, and their relative frequency. The most frequently cited manufacturers were Boeing, McDonnell Douglas, Cessna, and AirBus. The majority of responses came from major airline facilities. To date, 377 individual survey responses and 745 unique aircraft evaluations have been received. Of these responses, 296 individuals and 579 aircraft evaluations represent major aircraft operators. The remaining responses came from maintenance facilities responsible for regional and/or privately owned Part 25 aircraft. Figure 2 shows the relative percentage of responses for large and smaller Part 25 aircraft, respectively. The relative proportion of different aircraft types reported in the survey appears to be representative of the number in active service.

Figure 1. Aircraft Manufacturers Represented

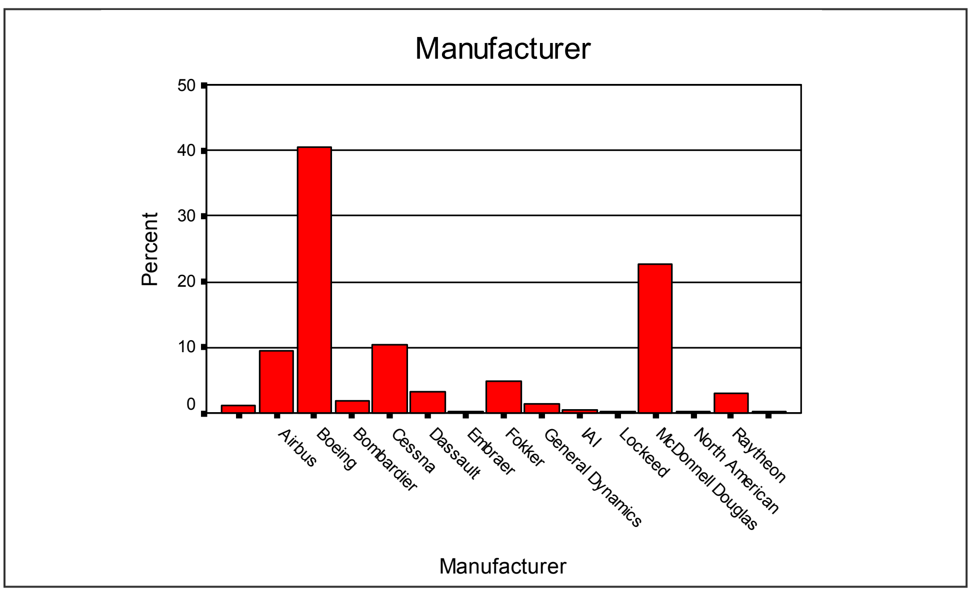
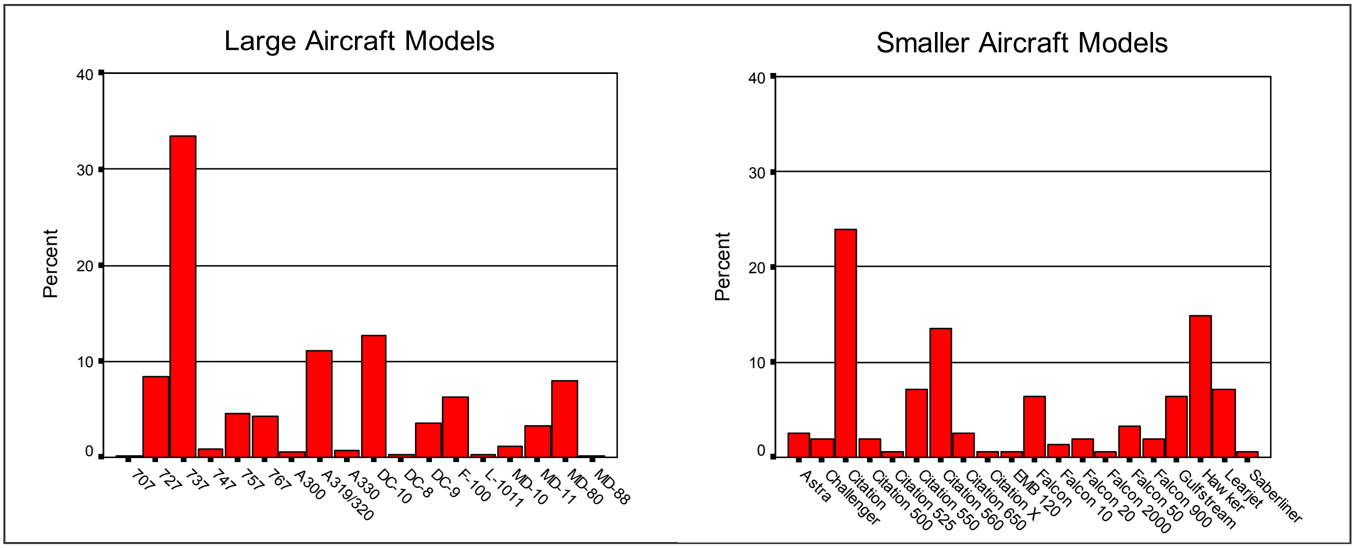


Figure 2. Aircraft Models Represented (Large and Smaller)



Demographics

A summary of the demographic characteristics of the survey respondents is shown in Table 1. The results reveal that our sample is almost exclusively male, is highly experienced, and consists of almost equal numbers of line and base maintenance personnel of which the vast majority are FAA certified.

Table 1. Respondent Demographics

Mean Age	The average age of respondents was 45 years, with the distribution ranging from 22 to 69 years. Age was normally distributed, with the bulk of responses coming from technicians 39 to 46 years of age.
Sex	With the exception of a single technician, all respondents were male.
Education	The majority of respondents (54%) indicated having some college education. 12.5% report having a Bachelor's degree or higher.
Certification	92% of all respondents and 94% of respondents working for major airlines were FAA certificated maintenance technicians.
Type of Maintenance	51% of responses were from technicians responsible for Line Maintenance, while the remaining 49% were responsible for Base Maintenance, or a combination of Line and Base Maintenance.
Experience	The average work experience reported was 14 years as a technician, and 13 years with their current company.
Military Training	58% of respondents report some military experience.

Manual Usage

Responses indicated that the Aircraft Maintenance Manual, Illustrated Parts Catalog, and Task Cards were the most frequently used technical documents. It should be acknowledged that because the survey sample included a large cross-section of maintenance operations, the technical documentation used by any particular technician will differ depending on whether they are doing line or base maintenance, and the degree to which they specialize in specific maintenance tasks. For example, scheduled base maintenance will rely more heavily on the use of task cards, while the unpredictable nature of line maintenance requires the maintenance manual and parts catalog to be used more frequently. It should be emphasized that the focus of this survey and evaluation was the Aircraft Maintenance Manual (AMM) and not job task cards. Interested readers should consult the work of Drury and colleagues[5] that focuses on the unique design and usability issues associated with task cards.

Error in Manuals

After establishing manual usage rates, technicians were asked to report how often they found errors in text procedures, illustrations, and diagrams. One of the larger goals of this project was to determine the degree of error present in technical manuals. Respondents were asked to rate, on a 5-point Likert scale, from "never" to "very often" how often they have encountered errors in manual test, diagrams, and procedures. While subjective, the results indicate that most respondents reported *rarely* or *never* finding errors in manual text (54%), illustrations (63%) and diagrams (66%).

General Manual Quality

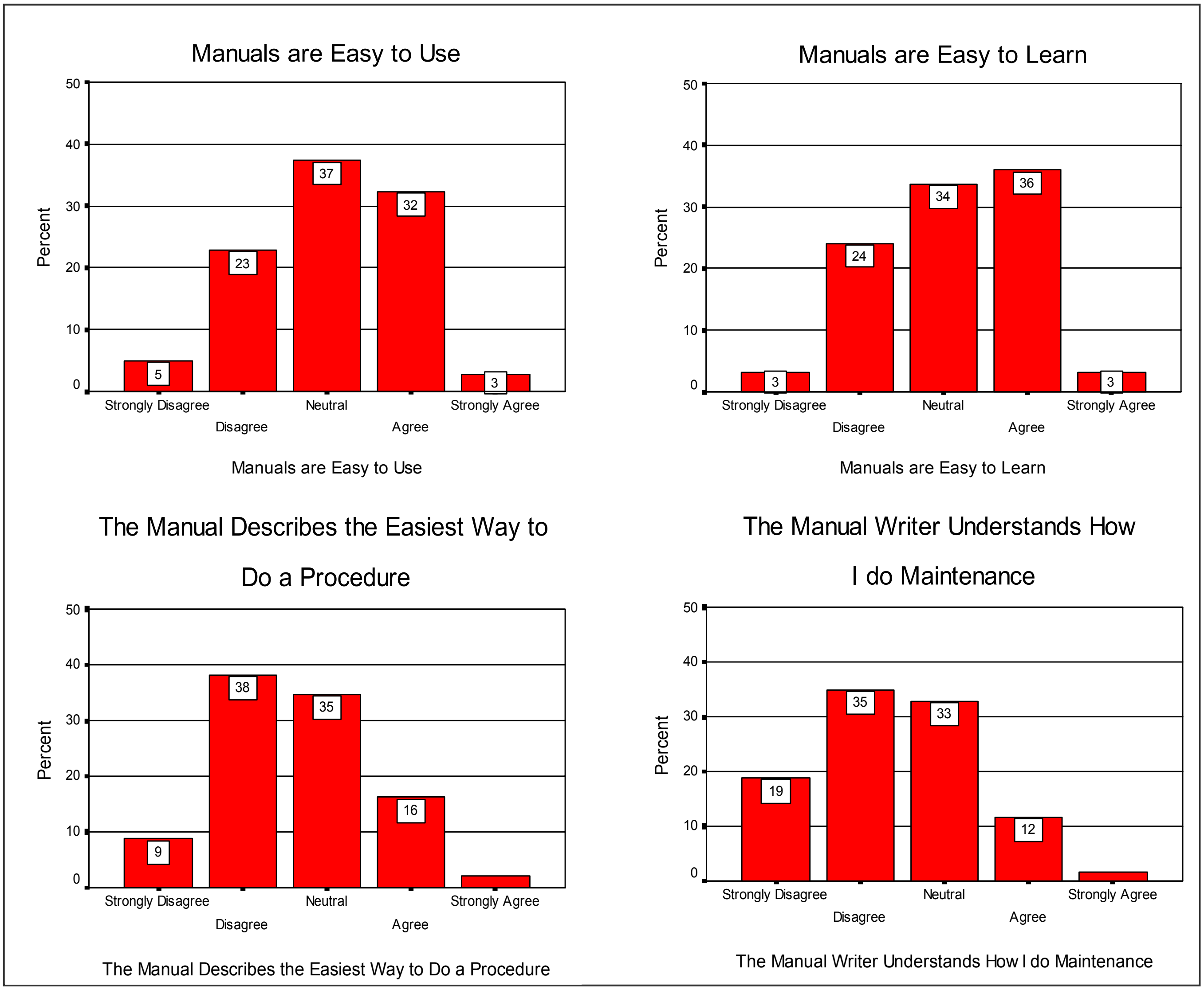
The next series of questions queried user perception of general manual quality. Respondents were asked to rate from "very poor" to "very good" the usefulness of manuals, the quality of manuals and diagrams, and the clarity of text descriptions. The following figures show that the technicians rate maintenance manuals as being very useful to the job they perform (74% "good" or "very good"), and perceive the manuals as being of generally good quality (56%), with good quality diagrams (54%) and text clarity (47%).

Usability

The next set of survey questions were designed to investigate user perceptions of manual usability. Usability issues surveyed included the ease of manual use, the consistency and clarity of the manual, and the depth of information. The respondent answers shown in Figure 3 are normally distributed with the mean centered near neutral or shifted slightly toward the positive end of the scale. In general, technicians consider maintenance manuals easy to learn, easy to use, clear, and consistent.

The final two usability questions assess how well the described procedures match the way technicians actually do their job. When asked to respond to the statement, "the manual describes the best way to do a procedure" 47% of technicians say they disagree or strongly disagree. The statement, "the manual writer understands the way I do maintenance" resulted in 54% of technicians responding that they *disagree* or *strongly disagree*.

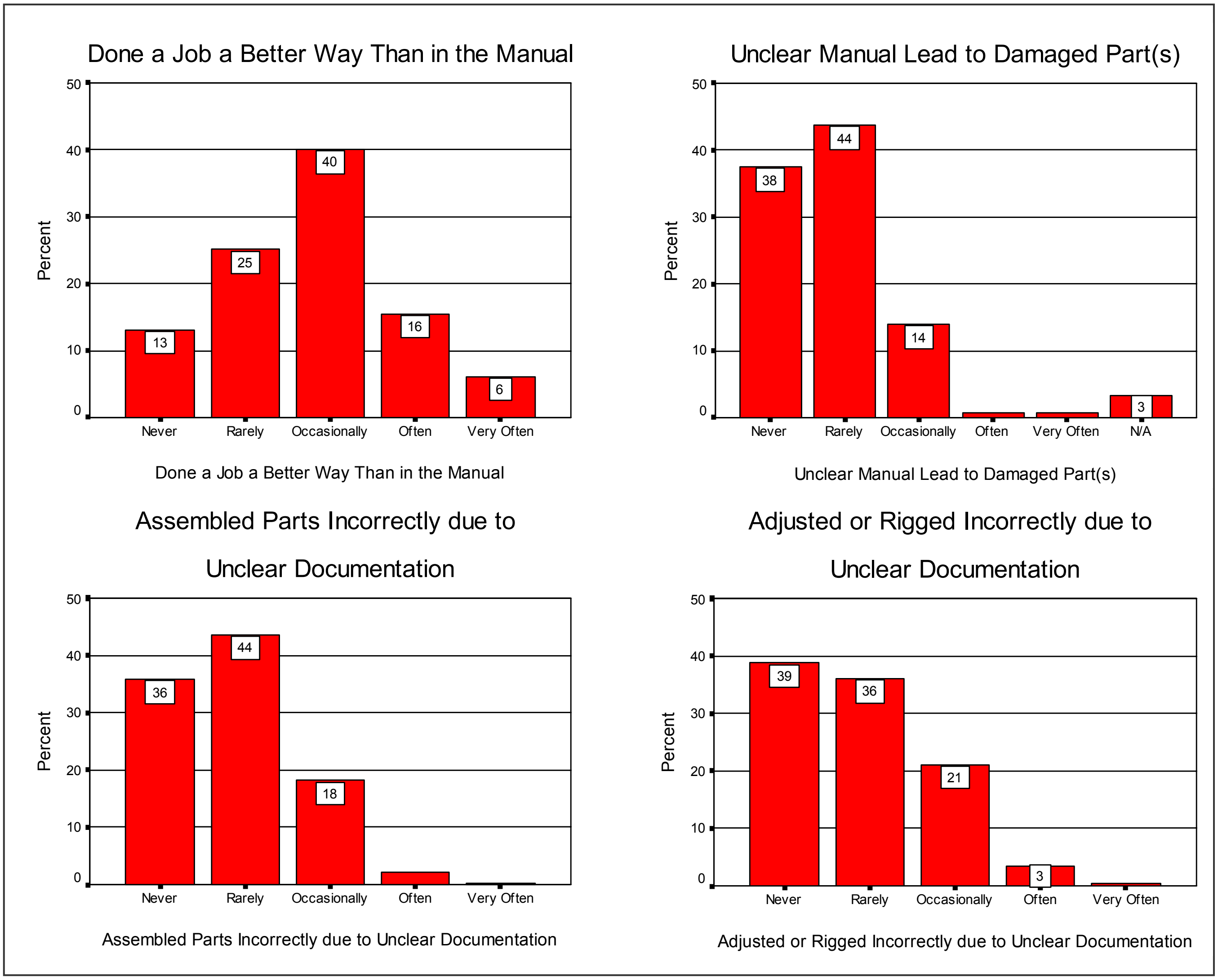
Figure 3. Measures of Manual Usability (cont.)



Impact of Manual Usability

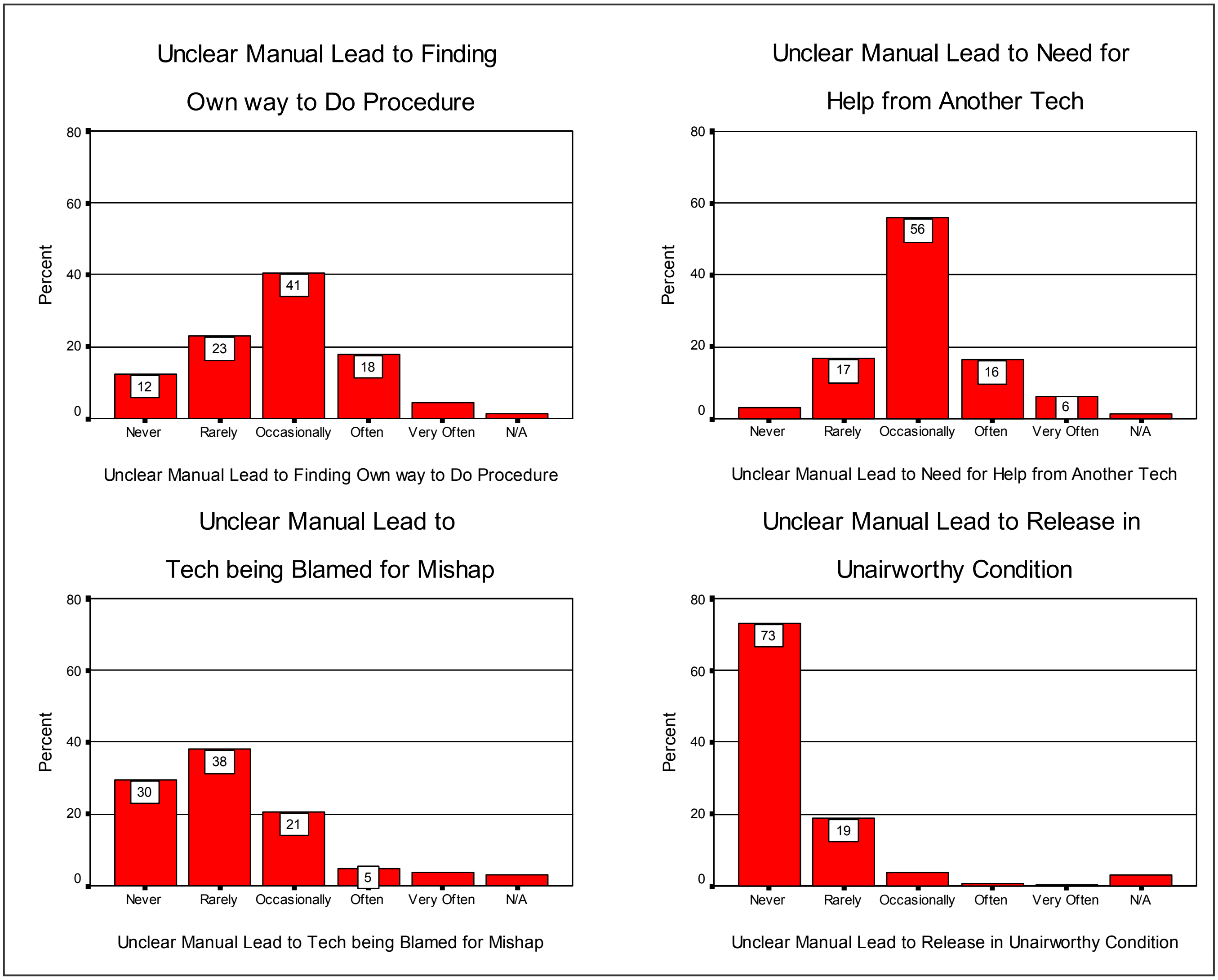
The following figures show the results of questions designed to assess the potential impact of document usability. As can be seen in Figure 4, 62% of the respondents reported completing a procedure in a way they considered "better" than what was described in the manual. As a result of unclear or misleading procedures, 18% of the respondents reported parts being damaged, 20% reported assembling a component incorrectly, and 25% report having adjusted or rigged a system incorrectly.

Figure 4. Reported Impact of Usability Problems



Seventy-eight percent of respondents reported that they consulted another technician when confronted with a confusing procedure and 64% reported finding their own way of performing a procedure. Only 5% reported that these difficulties resulted in an aircraft being released in unairworthy condition, but 30% report seeing a technician being blamed for a mishap stemming from difficulties interpreting the manual.

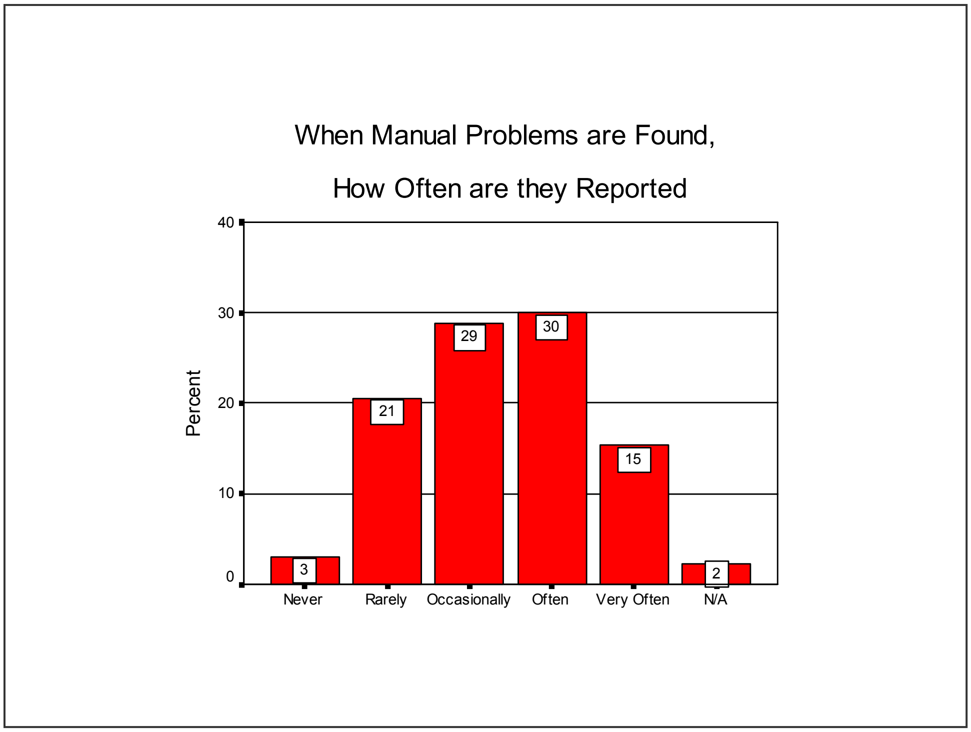
Figure 5. Reported Impact of Usability Problems (cont.)



Reporting Problems

In order to determine the effectiveness of the procedures intended to provide feedback to manufacturers about the problems users encounter within the manual, respondents were questioned about how likely a technician is to report an identified error. The results presented in Figure 6 indicate that 45% of respondents say they will *often* or *very often* report errors when they find them. Fifty-three percent reported that they report the errors they find only *occasionally*, *rarely* or *never*.

Figure 6. Reporting Identified Problems



Suggestions for Improvement

Finally, technicians were asked to make recommendations for improving maintenance documentation. In some cases, responses reflected local problems within their own organization. These responses included complaints of limited access to computers, or poor quality viewing and printing equipment that made the reproduced manual figures or text difficult to read. As such, these complaints are of a reflection of the degree of investment in technology to support maintenance activities than a reflection of manual usability.

The most common suggestion was to expand the use of electronic manuals, and the features they contain. Respondents commented that they would like to see a more extensive use of electronic documents and a better utilization of the capabilities of computers through video and audio information, improved search capabilities, and more extensive linking of diagrams, illustrations, and parts catalogs.

- “Make all reference material available on CD-ROM with search software implemented in all programs”
- “Ability to cross-reference parts with procedures”
- “Digitize all schematics and wiring diagrams”
- “All should be on CD-ROM with better graphics ability”

The second most cited suggestion support the fact that technicians do not have a problem with the accuracy of the documents, but take issue with the way procedures are written.

- “Make work steps easier to understand and make steps in a more logical order to accomplish work more efficiently”
- “Involve mechanics with the initial engineer/designer so the wording is more understandable”
- “Have experienced mechanics work with tech writers to be more articulate when describing work steps”
- “To really appreciate the problem pick something and go to a manual and see the length of time it takes to figure out what to do”
- “Tech pubs should refer to maintenance departments and establish a group to improve these items together”
- “Put the guy in some coveralls and have them work on the A/C before sitting down and writing the tech pubs”

The following groups of comments refer to the general level of detail used in diagrams and illustrations.

- “Quit putting a small picture on a page and a lot of numbers referring to parts, you need a magnifying glass to see where the arrows are directed”
- “Show more detail on a components and systems”
- “Outline the steps more clearly and if an item appears in the IPC, it should be mandatory to reference it in the manual”

Finally, the remaining comments refer to the speed at which manuals are updated or the speed of the revision process after problems are identified.

- “Quicker corrections to the manuals when I point out the errors”
- “Update illustrations and diagrams, replace old tech data”
- “Listen when someone reports an error”
- “Even when a problem is reported it doesn't seem to ever be corrected”

Note

If the results of this survey were limited to an assessment of the quality of technical manuals, the current system of documentation would appear, from the perspective of the users, to be successful. With only a few exceptions, technicians consider manuals informative, consistent, and accurate. The manufacturers put considerable effort into verifying the accuracy of facts and formatting of technical documents, and the technician’s rate them high in those areas. If the assessment stopped there, the results would indicate no need for improvement. However, when asked about the ease of use, efficiency, and suitability of the procedural information contained in the maintenance manual, a different pattern begins to emerge. The user’s complaints as reviewed above identify usability as a significant issue. This likely reflects the extent to which manufacturers fail to take into account the way technicians use maintenance documents and perform aircraft maintenance.

Interview Results

Many of the issues voiced during the site visits and interviews centered on the difficulties technicians have locating needed information in the maintenance manual. When asked for a subjective estimate of the total job time spent searching for information, most technicians reported that depending upon the job, as much as 50% of their time might be spent searching for information. The most common problems reported were determining effectivity and locating relevant procedures within the ATA chapter framework.

Effectivity

The aircraft manufacturer and associated parts suppliers are constantly working to improve their respective products. Engineering or design improvements are incorporated into production aircraft as they become available. Consequently, two aircraft of the same model and type can differ with regard to specific parts and components. This propensity for change continues once the aircraft is put into service. Vendors or suppliers may go out of business, engineering changes and service bulletins may lead to safety or regulatory related changes, and modifications may be made to upgrade avionics or optional equipment. The maintenance documentation must contain information specifying the parts and components unique to each aircraft.

Manual writers must provide references for all of the engineering changes, service bulletins, optional equipment, and superceded parts. When a technician begins a maintenance task, they must first establish the effectivity of all options that apply to the aircraft they are working on, as well as the status of any modifications or service bulletins. Usually, technicians must search through all of the possible options referencing the aircraft tail number against the parts list. Technicians repeatedly mentioned difficulty in determining effectivity of parts and systems. As noted above, technicians can spend as much as 50% of the total task time can be spent determining effectivity.

Navigating the ATA Framework

The original ATA specification 100, and the new *i*spec 2200 that replaces it, were developed to provide standards for the format and layout of technical manuals. In addition to page formatting and text layout guidelines, the ATA specification details an outline for the organization of material within the manual. As part of the ATA standard, manufacturers agree to conform to a common industry standard for chapter organization. For example, landing gear information will always be located in Chapter 32, and flight controls will always be detailed in Chapter 27. Standardization minimizes the time technicians need to learn to use new manuals, and makes it easier for them to switch from one manual to another. This standardization improves manual usability and user experience with manuals.

However, even when using the framework of the ATA specification, there are occasions when the manual writer must make decisions regarding the best location for component description or procedure details. For example, maintenance information pertaining to the wings is located in Chapter 57 and fuel systems are located in Chapter 28. Because fuel tanks are located in the wings, interfacing parts belonging to the wing may appear in diagrams of the fuel system but only be referenced in the manual chapter dealing with the wing. In this case, the technician must determine which system each component belongs to and where the relevant information can be found. These organization decisions are common to all parts of the aircraft and must be made throughout the manual. Because there is some leeway in the organization of information within the chapter structure, writers may make decisions based on engineering classification of systems or ease of writing. While the design and manufacturing processes may suggest natural answers to these questions, the response of technicians indicates that the organization choices made by writers often creates confusion and difficulty for technicians when they attempt to find information.

Design of Procedures

The third issue raised during site interviews was the ordering and breakdown of procedural steps. Rather than listing the same procedural steps every time a similar task must be accomplished, most manuals will list them once, and call them out when applicable. This subtask call-out arrangement reduces overall manual size, ensures the consistency of information, and increases efficiency of document revisions. If a procedure must be revised, it is easier to change one instance rather than multiple instances of that information. In a paper-based manual, the subtasks referenced in a maintenance procedure may be distributed throughout the manual, forcing the technician to jump from one section to another. In some cases, a procedure will call for only select steps of a given sub-task, further fragmenting the flow of procedural steps. This subtask distribution is well suited to a linked, electronic document that allows the user to follow links to each subtask and then return to the original procedure. In paper or microfilm formats, the technician must manually search for, and retrieve the subtask information. The time spent searching for relevant subtasks and the disruption of workflow increases the likelihood that a technician may miss steps, or lose their place within the procedure.

Discussion

Summary of Main Findings

Because of concerns about the potential impact on safety, manual error has received greater attention recently. This is partly in response to a number of aircraft accidents attributed, at least in part, to maintenance errors. In the absence of hard data, the magnitude of this problem could not be estimated. This project represents an attempt to determine the extent and potential impact of errors in aviation maintenance manuals.

In general, the results indicate that the number of errors in fielded manuals may be relatively low given that most respondents reported rarely or never finding errors in text (54%), illustrations (63%) or diagrams (66%). One might be alarmed to see that roughly 35% to 45% of respondents reported occasionally or often finding errors in these areas. However, many of these errors, such as misspellings or format errors would have little impact on maintenance or aircraft safety.

Comparisons of errors found in text versus diagrams shows that errors appear to be more frequent in text. This does not mean that textual information is necessarily less accurate than the information presented in diagrams or illustrations. This pattern more likely reflects the fact that text procedures represent a proportionally larger part of the manual, or it may be the result of the difficulty of putting complex procedures and descriptions into words versus presenting that information in a graphic form.

User feedback is one of the primary factors influencing the development of technical documentation. Each company employs its own set of procedures to develop a manual they think users will accept. In addition to user satisfaction, these procedures must strike a balance between a number of competing demands including, manual development costs, time constraints, regulatory requirements, and safety. Each manufacturer has attempted to achieve a balance among these competing demands and the variety of approaches adopted reflects the uniqueness of those solutions. Considering that the majority of users (56%) rate the quality of manuals as being *good* to *very good*, it would appear that that the demands of users are being met.

Quality of Manuals

If the manufacturers perception of the quality of their manuals is based on the feedback obtained from users, this perception may be in error because they do not know the number of errors that go unreported. More importantly, it places a greater emphasis on factual and typographic error, (e.g. incorrect part numbers and misspellings), while providing little information about the usability of the document and procedures. It is quite possible for a document to be factually correct, free of spelling, grammar, and formatting errors, yet fall short of the goal of good usability. For example, Patankar and Kanki[6] outline changes in the engine change procedure of a Boeing 737 that resulted in significant decrease in total job hours. The factual information remained the same, but improvements in the usability of the document resulted in a more efficient, and presumably, safer procedure.

The number of *disagree* and *strongly disagree* responses to the questions, “the manual describes the best way to do a procedure”, and “the manual writer understands the way I do maintenance” reflect a problem with manual usability. What is of issue here is whether the procedural steps can be easily followed, whether procedures progress in a logical and efficient manner, and whether the task instructions take into account possible extenuating circumstances or the difficulty of certain tasks. When writing a task procedure the writer must decide what order to follow, the number and extent of warnings to include, how much background information to include, and how much detail to provide. In many cases, these choices are made based on either design standards or personal experience. Ideally, these decisions should be guided by observation of individuals performing the task and/or feedback from technicians. The farther removed the writer is from the task demands, the less aware they will be of potential usability problems.

Clearly, there is a need to provide maintenance technicians with documentation that not only conveys the technical information necessary to maintain an aircraft, but also presents it in such a way that it best matches the way technicians do their job. All manufacturers have systems in place to gather feedback from operators about the accuracy of manuals, but gathering data about user perceptions of manual usability has not traditionally received as much attention. This type of feedback requires more detailed communication from the operator, and a greater commitment from manufacturers to gather that feedback. The majority of current response forms and suggestion reporting methods are tailored more toward the traditional idea of error being limited to incorrect information. When evaluation of manual quality is extended beyond information error into issues of document usability a reactive approach becomes less effective because users are unlikely to report usability problems, and even less likely to make non-technicians able to understand those problems. Users may not take time to provide feedback, may fail to articulate the problem adequately, or the writer may fail to appreciate the cause or extent of the users difficulty. Analysis of survey responses to the question, “How often do you report errors when you find them?” reveals that in many cases technicians simply do not take the time to report errors. Because users represent the last line of defense in ensuring manual quality and accuracy, any failure to report an identified error can be considered a degradation of the entire system. The goal then becomes one of determining why users might fail to report errors, and how the reporting system might be improved. In both the on-site interviews and survey comments technicians frequently commented that they received little feedback or saw no changes to the manual as a result of their suggestions. If there is a perception that no one is listening to their input, the technicians will simply stop providing feedback. What remains unclear is where this breakdown is occurring. Supervisors may fail to pass information on to the writers and engineers within their operator, those writers and engineers may fail to pass it on to the manufacturer’s service representative, or the manufacturer may fail to adequately respond to the input of the service representative. In many cases a change request may be denied but the reporting technician is left unaware of reasons for this decision. If technicians believe that their comments were ignored they will be less likely to report problems in the future. In order for the reporting process to work, a greater commitment is required from both the operator and the manufacturer to ensure that identified problems are reported in sufficient detail, and a follow-up response is provided to the reporting technician even when no changes are made.

Potential consequences of usability problems in technical documents include the safety, speed, and cost of aircraft maintenance. In a complex, time-limited environment like aircraft maintenance, these factors are interdependent. Every time a technician has difficulty finding information in the manual, the speed of maintenance is slowed and revenue is lost. Because of the financial impact and schedule demands, the pressure to complete work quickly can push individuals to take short cuts. If the technician has difficulty understanding the wording of a manual procedure they may be motivated to devise an alternate method of completing that task, or ask another technician for help. With the average level of experience represented in this survey (13 years), this may not result in a problem. However, whenever users are pushed to work around usability problems, the potential for safety violations increases.

Some aspects of manual usability, such as formatting consistency and reading level can be controlled through standardization and guidelines. The need for clarity and consistency across manuals has been the motivation for the ATA guidelines regarding the layout and organization of maintenance documentation. The ATA Spec 100 / *i*spec 2200 has been an effective means of establishing a baseline for manual quality and structure. The pattern of responses to survey questions pertaining to manual quality, consistency, and ease of use suggest that the standards adopted by the ATA have been effective. The use of consistent style and formatting is one important aspect of document usability. However, within the framework of the ATA specification, the writer must make decisions about details such as the ordering of procedural steps, the wording of procedures, the use of illustrations, and level of detail. Questions about wording and sentence structure can be addressed with the use of restricted vocabularies or style guides, but the unique nature of each maintenance procedure limits the usefulness of any checklist or standard method for describing a procedure. Writers and engineers must rely on their writing experience and knowledge of the aircraft systems when deciding how best to describe a procedure. Likewise, a technician will rely on their maintenance experience and knowledge of aircraft systems when interpreting and applying maintenance information. Unfortunately, the experience and knowledge of the writer and engineer may be quite different from the experience and knowledge of the technician. This potential mismatch can result in other usability problems in technical documentation. At least one participating manufacturer has started to address some of these issues by validating maintenance manual procedures. Unfortunately, the responses included in the current survey do not include enough references to validated manuals to ascertain the effects on user perception.

Future Usability Issues

The responses included in this survey apply primarily to paper-based manual formats. There is a slow but steady trend to replace these manuals with computer-based maintenance information. The move from paper-based to electronic manuals will address many of the usability problems reported by technicians. Electronic manuals can be updated and distributed quickly, take up less space, and can make searching for information much easier. In addition, they may include text, audio, and video presentations to provide a more detailed description of procedures. Even with the potential benefits of moving to electronic manuals, the change of format introduces new usability issues. These include the design of the interface, search functions, size and readability of video displays, document navigation, and equipment reliability. Every subsequent development in the delivery of technical information will also require careful scrutiny of usability concerns.

Implications

The results of the survey suggest that the users of aviation technical manuals generally perceive the manuals favorably. They do not report significant problems with the accuracy or general quality of the documents. The main criticism shared by most users pertains to usability. More specifically, users comment that in many cases the document procedures are inefficient and/or fail to consider the demands of the maintenance environment. Considering that these concerns were shared by technicians using manuals from a diverse set of manufacturers it is expected that improving the usability of tech documents may have a broad range of benefits ranging from improved user satisfaction to improve safety and savings in maintenance costs.

Acknowledgements

This work was funded by the Federal Aviation Administration under grant number: 00-C-WSU-00-12. The FAA William J. Hughes Technical Center Monitor was Cristina Tan.

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